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PERSONAL NOISE DOSIMETRY SURVEY OF VARIOUS OCCUPATIONAL GROUPS AT FOUR POTASH MINES IN SASKATCHEWAN

K.C. BUTLER

ELLIOT LAKE LABORATORY

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by

K.C. Butler*

ABSTRACT

This report presents a personal noise dosimetry survey of four Potash mines in Saskatchewan over a four month period. Most job categories on the surface and underground were surveyed at least once, and the occupations with higher noise exposures were surveyed numerous times. Personal noise dosimeters were worn by the workers for a minimum of 8 hours and the data were analyzed on a personal computer. The majority of employees tested had time weighted averages (t.w.a) over 85 dBA, and would, therefore, be advised to wear approved hearing protection. The majority of occupations with a greater noise exposure are in production, but some maintenance occupations had high dBA levels as well. Further noise research in the Potash mines of Saskatchewan is recommended. This could include audiometric testing of employees, as well as investigations of problem noise areas and possible control measures.

Keywords: Noise exposure; Noise dosimeter; Time weighted average.

*Technician, Elliot Lake Laboratory, CANMET, Energy, Mines and Resources Canada, Elliot Lake, Ontario.

DOSIMÉTRIE DU BRUIT TOUCHANT DIFFÉRENTS GROUPES DE MÉTIERS DANS QUATRE MINES DE POTASSE EN SASKATCHEWAN

par

K.C. Butler*

RÉSUMÉ

Ce rapport présente une étude dosimétrique sur le bruit touchant les travailleurs de quatre mines de potasse de la Saskatchewan pendant une période de plus de quatre mois. La plupart des types de métiers concernant les activités souterraines ou en surface furent analysées au moins une fois, alors que les emplois exposés à de plus hauts niveaux sonores furent étudiés plusieurs fois. Des dosimètres personnels de bruit ont été portés par des travailleurs pendant un minimum de huit heures et les données ont été analysées à l'aide d'un ordinateur personnel. La majorité des employés testés sont en contact avec des moyennes d'intensité sonore (m.i.s.) de 85 dB et devraient en conséquence porter des appareils réglementaires de protection contre le bruit. La majorité des métiers soumis aux plus haut niveaux sonores sont en production, bien que quelques postes en entretien rencontrent eux aussi de hauts niveaux de décibels. D'autres recherches sur le bruit sont recommandées au sein des mines de potasse, ce qui pourrait inclure autant des tests audiométriques sur les employés qu'une recherche des zones sensibles au bruit et des mesures pour corriger ce problème.

Mots-clés: exposition au bruit; dosimètre pour le bruit; moyenne d'intensité sonore.

*Technicien, Laboratoire d'Elloit Lake, CANMET, Energie, Mines et Ressources Canada, Elliot Lake, Ontario.

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INTRODUCTION

Saskatchewan has 40% of the world's potash reserves, estimated at 130 billion tonnes muriate of potash with a capacity of 12.9 million tonnes KCl per annum, providing employment for 3,300 people. The fertilizer industry accounts for 90-95% of the potash consumed. Up to 95% of Saskatchewan's production is exported abroad, with 70% going to the United States, while the remainder is consumed domestically (1).

The mining techniques used in potash mines are unlike the drill/blast/muck system in hard rock mines. The method employed by the potash mines tested, uses a continuous mining process whereby mining machines (borers) cut several passes through an area, with the mined ore being transported in the circuit of a series of conveyor belts and skipped to the surface. The number of passes made, and the number of levels cut are dependent upon the geology and ground conditions of the particular area and the mining techniques developed at the mine.

Noise surveys at various potash mines have been divided into two major areas: underground, and surface. Underground noise sources are trucks, jeeps, ventilation fans, skip and cage, sledge hammers, Hilti guns, mobile diesel equipment, pumps, mining machines, conveyors, compressors, compressed air equipment and compressed air. Surface noise sources are exhaust fans, pumps, dryers, cyclones, compactors, compressed air equipment and compressed air, diesel trucks, forklifts, and tractors.

This noise survey was initiated to determine specifically which work groups had higher exposures to noise thereby helping to define the requirements for audiometric testing. These tests would also help to assess the authenticity of compensatory claims. Finally, it would alert officials to occupations with higher than desirable exposures to noise.

FUNDAMENTALS OF NOISE

Two important aspects of a sound wave are the intensity (amplitude), and the pitch (frequency). Noise measurements are usually only thought to be associated with the intensity level, but frequency is also an important factor. Higher frequencies can cause greater hearing damage (2) since most hearing impairment occurs in the 4-6 KHz range (3).

Sound intensity measurement uses two means to achieve a decibel (dB) value, either pressure, or power, and both are expressed as a ratio. For the Sound Pressure Level (SPL), a reference pressure of 0.00002 Nm, or 0.0002 μbar have been chosen since this is thought to represent the smallest sound an average young adult can hear in quiet surroundings (4-6) and is given by the following formula:

$$SPL = 10 \log (P/P_{ref})^2$$

$$= 20 \log (P/P_{ref}),\ dB \qquad \text{Eq 1}$$

where p is sound pressure in N/m^{-2} or Pa, and P_{ref} is reference pressure of: $2.0 \times 10^{-6}\ Nm^{-2}$.

The Power Level ratio (PWL) of determining the decibel level and sound intensity is expressed in W/m^2 which is the difference between the atmospheric and the actual pressure during a compression or rarefaction of a sound wave (4-6), and is given by the following formula:

$$PWL = 10 \log(W/W_{ref}),\ dB \qquad \text{Eq 2}$$

where W is the acoustic power of the sound source in watts, and Wref is the reference power which is: 10^{-12} W.

The Occupational Health and Safety Branch of the Government of Saskatachewan has ruled the "equal energy principle" of the International Organization for Standardization (ISO) is to be used (7) to determine the dB level and length of exposure. From Equation 2, a doubling or halving of

acoustic power (watts) results in a 3 dB increase or decrease. Using the 85 dB criterion where this level is equal to a 100% dose over an 8-hour period, every 3 dB increase over 85 dB results in a doubling of power and dosage and a halving of the allowable exposure. Conversely, every 3 dB decrease below 85 dB produces the opposite effect.

NOISE SOURCES AND CONTROLS

There are three types of noise sources (8):

Mechanical	Fluid	Electrical
Vibration	Pneumatic	Transformer hum
Friction	Hydraulic	Arcing
Impact		

Apart from the above, noise can be further divided into three components (5,6,9), namely: noise source, path of noise and the receiver.

Engineering solutions for the above are to modify the forces within the source by redesigning, servicing or isolating the noise source. The noise path may be altered by the use of screens and/or enclosures, or moving the operator away from the noise source. The receiver can be enclosed or provided with hearing protection (4,6). The noise source or the path are the ideal means of dealing with a noise problem, but often the only practicable solution is to engage the problem at the receiver.

Because personal hearing protection is used considerably, there has been extensive research into this field. Sound energy reaches the ear by four different means (10):

(1) through bone conduction (skull);

(2) vibration of the protective device;

(3) passing through leaks in the protector;

(4) acoustic leaks around the protective device.

Since the human ear is most sensitive to damage in the 1 to 4 KHz range (2), sound absorbing material is designed to attenuate that range of frequency. Ear protection devices fall into four categories: ear plugs, semi-inserts, ear muffs and helmets. These protection devices should have the following qualities: they should attenuate at least 20 to 30 dB, be comfortable and not have harmful side effects, e.g., skin disorders, ear infections (10). Yet, in the real world, often none of these criteria are met. In many cases attenuation is no better than 10 to 15 dBA, or 10 to 15 dBA less than the figure claimed by the manufacturer and this problem is quickly reduced with usage, due to wearing out of the cushion, or reduction in clamping force (11). Sometimes, improperly matched ear muffs and plugs may provide less protection than that provided by each of the protectors worn alone (7).

EXPERIMENTAL PROCEDURE

Testing at the four mines was done using a personal noise dosimeter, the Metrologger db 301, manufactured by Metrosonics Inc. The db 301 is a pocket size data logger which records time history. This instrument has a dynamic range of 64 dB, and a frequency response which is 'A' weighted, meaning the instrument is designed to respond to frequencies in the range of normal human hearing. A plug-in PROM (Programmable Read Only Memory) allowed, in these tests, for the dynamic range to be set from 60 to 123 dB with a baseline of 60 dB. During operation, each minute of noise exposure gives 240 samples (4 samples/sec), and each minute is stored sequentially as a count. An L_{eq} value is calculated based on the 3 dB exchange rate using the following formula:

$$L_{eq} = 10 \log (1/N) \Sigma 10^{0.1 L_i} \qquad \text{Eq 3}$$

where, N is the number of samples , and L_i is the value of each sample in dB.

These sequential values are stored in the logger's memory. The type of microphone employed was a Quest 1/2 inch ceramic, with a 1 m length of cable.

The data from the logger were transferred into a computer interface model DL600 manufactured by Leq Instruments of Brampton, Ontario. From here the data were processed by an Apple II Plus computer using a program provided by Leq Instruments. The data from each logger were processed to give a cumulative value and percent dose based on the 85 dB criteria of the ISO with 3 dB increments. The program provided an amplitude distribution and a time history graph.

At each mine, a slate of job categories were listed to determine which occupational groups would be tested. Sample size was determined by the following:

(1) the perceived noise exposure to that group;

(2) the number of employees in the group population;

(3) the number available each day sampling was done;

(4) the availability of different individuals within the population;

(5) the work schedule of individuals;

(6) the length of time sampling could be done.

At each mine testing was divided into two groups: underground and surface. The schedule was such that each group would be completely tested before moving onto the next. Every morning 8 to 10 selected voluntary employees were issued a calibrated dosimeter and given a brief explanation on its use. The dosimeter was enclosed in a protective aluminum case which in turn was mounted to the safety belt with the microphone clipped to the collar.

The dosimeter was worn throughout breaks and lunch periods. After eight hours the logger was collected and the data were dumped into the computer for analysis. These processed data were analyzed for current and cumulative L_{eq}, current and cumulative percent dose, maximum and minimum dBA

levels, amplitude distribution and L_{eq} time history graphs, with a hard copy printout being given and only the raw data being stored on disc. Following this, the battery was replaced and the unit's calibration was checked. If recalibration was necessary then the day's data from that particular logger were considered unreliable and discarded.

RESULTS AND DISCUSSION

The noise survey was conducted over a period of four months with a total of 608 sucessful tests distributed among 104 job categories. A failure rate of 10 to 20% per day was considered normal. Dosimeter reliability was quite acceptable. At the end of the project only 2 out of 13 instruments failed and could not be repaired on site.

Microphones, however, were unreliable and had to be constantly repaired. The 1/4 inch microphone which came standard with the dosimeter was replaced by a Quest 1/2 inch model. This microphone required a LEMO connector to be soldered at the Elliot Lake Laboratory. However, this connection resulted in numerous failures due to solder joints breaking.

In the final analysis of data it was decided that there would be no attempt to compare the mines to one another. Because of variations in job description and duties, mine and milling techniques and design, only the different occupations within each mine are compared. The graphs and tables serve only to indicate the relative noise exposure for the various occupations within each mine.

The figures in the tables are structured so as to show the number of completed tests for each occupation, the mean time weighted average, and the rank, from noisiest to quietest. The vertical scale of the lower graph shows the dBA level with the standard deviation. Because many authors (3,6,7,11) have discussed the implications of short periods of loud noise, the maximum

dBA value has also been shown, though these values should not be confused with impact noise. The vertical scale on the top graph shows time weighted average as a percentage of dose and allowable exposure. This graph, when compared to the bottom one serves to indicate how relatively small differences in dBA between occupations can develop into large differences when viewed as a percent of allowable dose, since this is the criterion used to determine the exposure time.

It should be emphasized that per cent dose and allowable exposure time on the y-axis of the upper graph are for the unprotected individuals. For those wearing approved hearing protection the per cent dose is reduced, thereby increasing the allowable exposure time. As stated in the introduction, an attenuation of 10 to 15 dBA is the practicable maximum to be expected, and for a cumulative dBA - L_{eq} exposure greater than 95 dBA an individual wearing proper hearing protection may still be overexposed.

To verify some excessive noise levels, a sound level meter, type 2225, manufactured by Brüel and Kjaer Instruments of Naerum, Denmark, was used at each mine. This sound level meter was used for routine testing of various areas and the results were compared with the values from the loggers. Apart from the dosimeters being calibrated daily, a tone of 94 dBA at 1 KHz was occasionally loaded into the dosimeter and cross-referenced on the computer.

The potash ore, Sylvinite, a sedimentary rock, is made up of about 45% KCl, 55% NaCl, and 5% clay. The compressive strength of the Sylvinite is approximately 1/10 that of the Quartzite found in the Elliot Lake area (12). Potash, because of its low density and relative softness, absorbs sound waves and this affects the reverberation time. Crocker and Kessler (13) have related the sound absorption of the material to its hardness and density. Reverberation time, 'T', is defined as the time required for sound to decay 60 dB (3,13), and it is affected by the characteristics of the ground being mined

as well as the tunnel dimensions and the absorption of the room. Depending on which pass the mining machine is on and the dimensions of the tunnel, the noise level may vary considerably.

The mining machines are electrically powered via cables from the surface. Noise is produced by various electric motors on the mining machine, the hydraulics, the ventilating fan, the cutting bits/chains, and the conveyor belt. Usually, the greatest noise exposure is to the operator, but the back-up operator(s), whose main duty is to direct the ore from the mining machine's conveyor belt to the main conveyor, is (are) often exposed to high noise levels from the belts and impact noise from falling ore.

The number of tests per occupational category was due to factors which affected the scheduling. One problem which arose, mostly in the underground production crew, was the men exchanging duties and doing various jobs during their shift. Data from these individuals, who were tested, were felt to be acceptable because this job substitution was considered part of a normal shift. Other job categories in production also have high noise levels which are due to the operation of diesel equipment. Maintenance crews usually have lower time weighted averages since repair work in the field is on equipment which is not in operation and in the shop, the noise is intermittent and usually only occurs when power tools are being operated, or repaired equipment is being tested.

In the mill, during normal production, the noise level may vary considerably from area to area, and generally the use of hearing protection is required. Specific occupations, such as sandblaster/painter have noise levels which are variable, whereas others, particularly mill production crews are exposed to constant noise levels.

Though all four mills are noisy, there are nevertheless significant variations in time weighted averages, which are due, in part, to plant layout,

building material (concrete or steel grating floor), maintenance schedule for the equipment and variations in the milling process. Also, in each mine, employees during their shift have specific duties, as well as regulations which limit the amount of time which may be spent in lunch rooms or control rooms, away from the noise. Since the data from the various mines are not being compared to one another, the results within each mine include a comparison of surface and underground operations with a brief discussion of the noisiest occupations which is given below.

MINE A

There were a total of 134 tests, with 75 underground and 59 on the surface. Of the various surface job categories, 4 of 18 had cumulative dBA values of 85 dBA or less. The highest noise level occupations were in the production crews, with the maintenance and loadout crews having lower noise levels.

For surface operations, most production employees had high readings, but maintenance categories such as Stationary Engineer, Industrial Technician and Sandblaster/Painter registered the highest noise levels. The time weighted average for Instrument Technician and Sandblaster/Painter varied from day to day due to the nature of their work, and for occupations such as these hearing protection is worn as required. Most production employees should wear hearing protection continuously since the background noise is usually over 85 dBA.

Of the underground job categories tested, 4 of 11 had a time weighted average of 85 dBA and under. Like the surface operations, occupations with the highest noise levels were in production, with the exception of the maintenance lubricator, whose main source of noise is the lubrication vehicle.

Table 1 - Number of tests, time-weighted average, and rank for various job categories on surface at Mine A.

Job Category	No. of Tests	Time Weighed Average (dBA)	Rank
Utility Operator	3	92	3
Grinding and Desliming Operator	3	93	2
Flotation Operator	4	92	3
Dewatering, Drying & Tails Operator	3	91	4
Product Screening & Dispatch Op.	3	90	5
Compaction Operator	3	86	8
Reagent Operator	2	86	8
Crystallizer Operator	3	91	4
Chute Operator	2	83	10
Mobile Equipment Operator	3	92	3
Weightmaster	2	84	9
Electrician	3	89	6
Industrial Mechanic	9	81	11
Welder	3	87	7
Sandblaster/Painter	4	92	3
Stationary Engineer	4	94	1
Industrial Technician	1	93	2
Shift Foreman	4	83	10

Table 2 - Number of tests, time-weighted average, and rank for various job categories underground at Mine A.

Job Category	No. of Tests	Time Weighted Average (dBA)	Rank
Miner Operator	16	98	1
Back-up Operator	11	90	5
Rehab Operator	1	90	5
Wagonmaster	1	94	3
Service Crew Operator	14	91	4
Lubricator	2	95	2
Electrician	8	85	6
Welder	4	81	8
Heavy Duty Mechanic	5	83	7
Industrial Mechanic	9	85	6
Supervisors	4	91	4

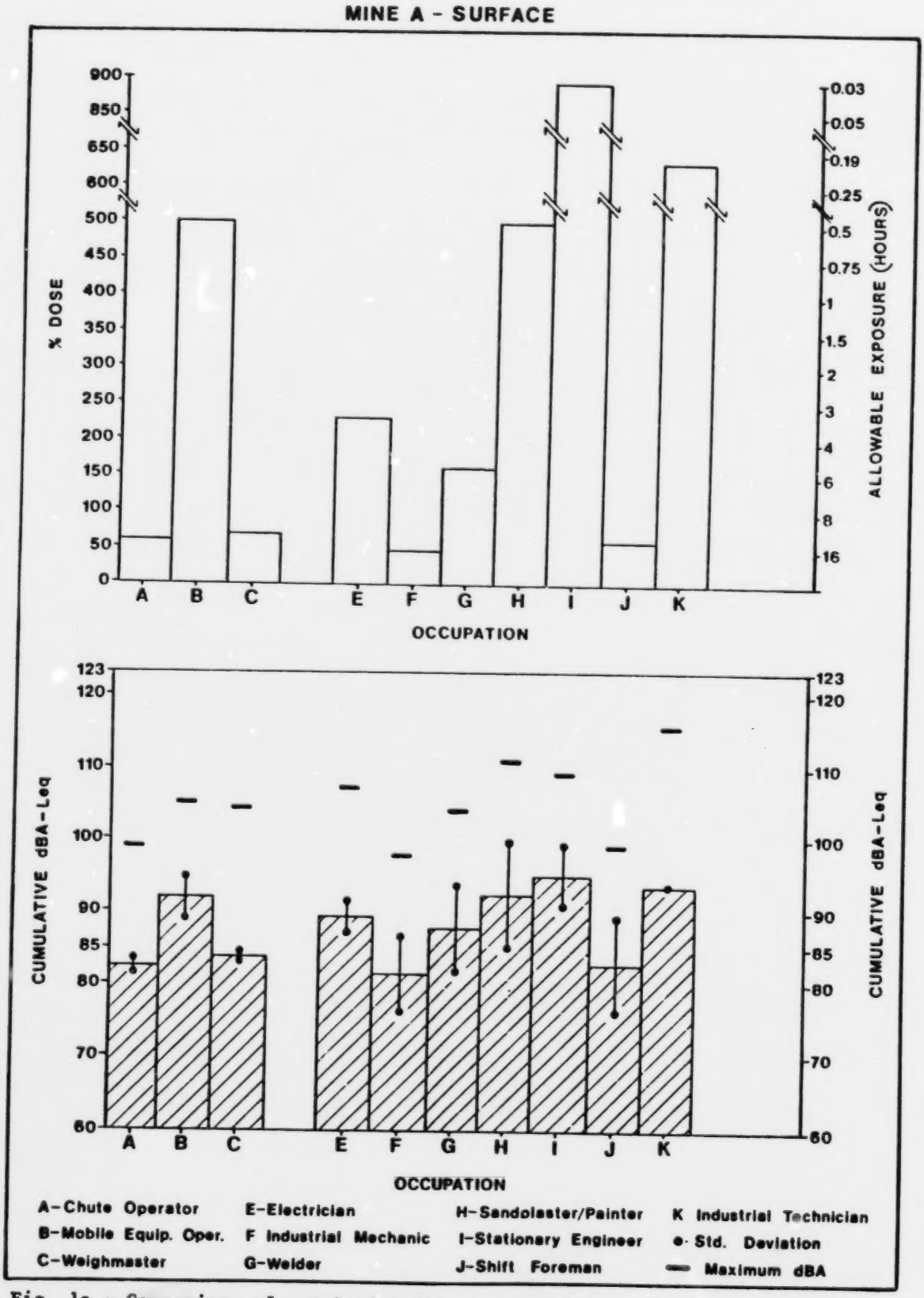

Fig. 1a - Comparison of cumulative dBA to percent dose/allowable exposure for each occupation for surface at Mine A.

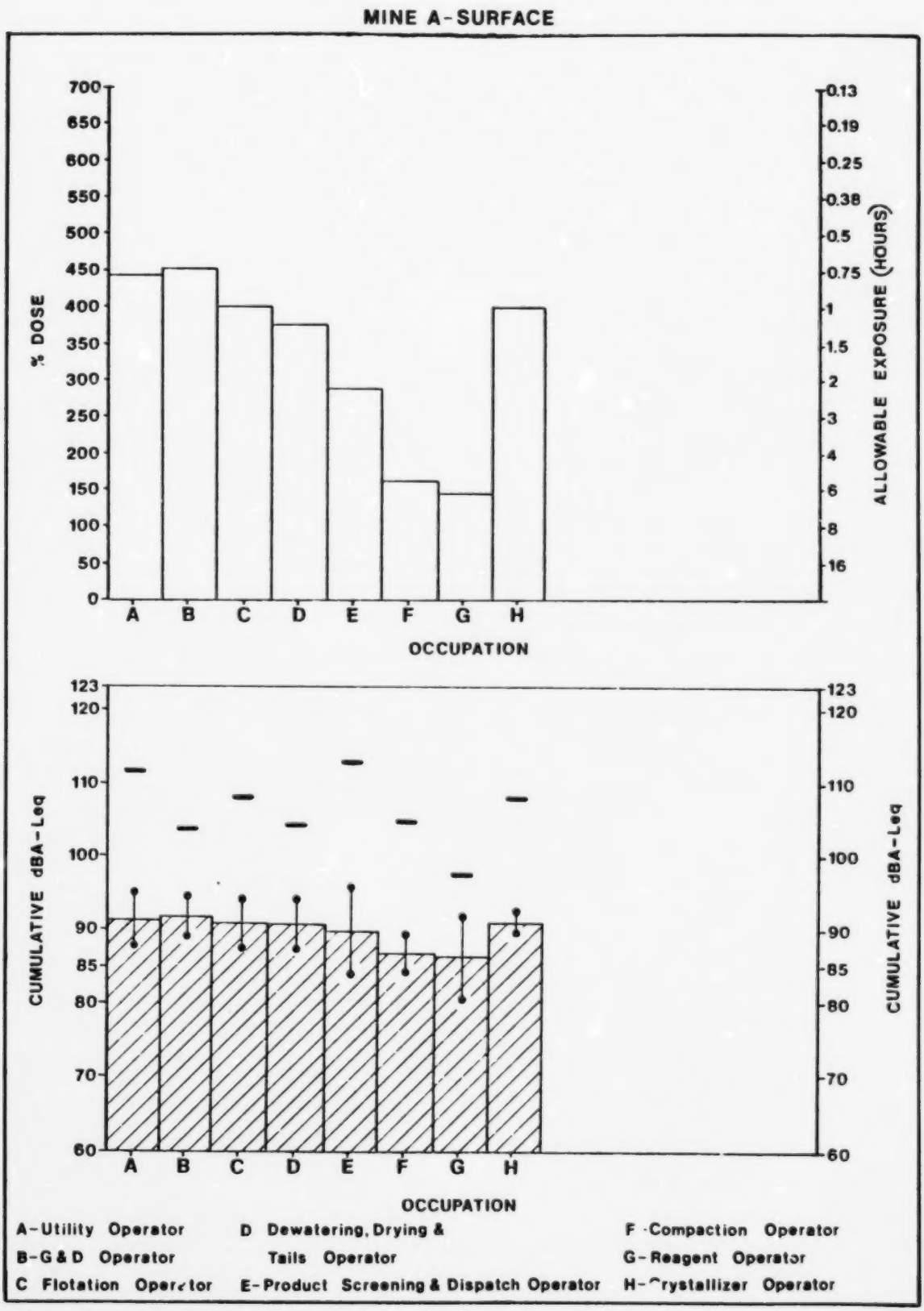

Fig. 1b - Comparison of cumulative dBA to percent dose/allowable exposure for each occupation for surface at Mine A.

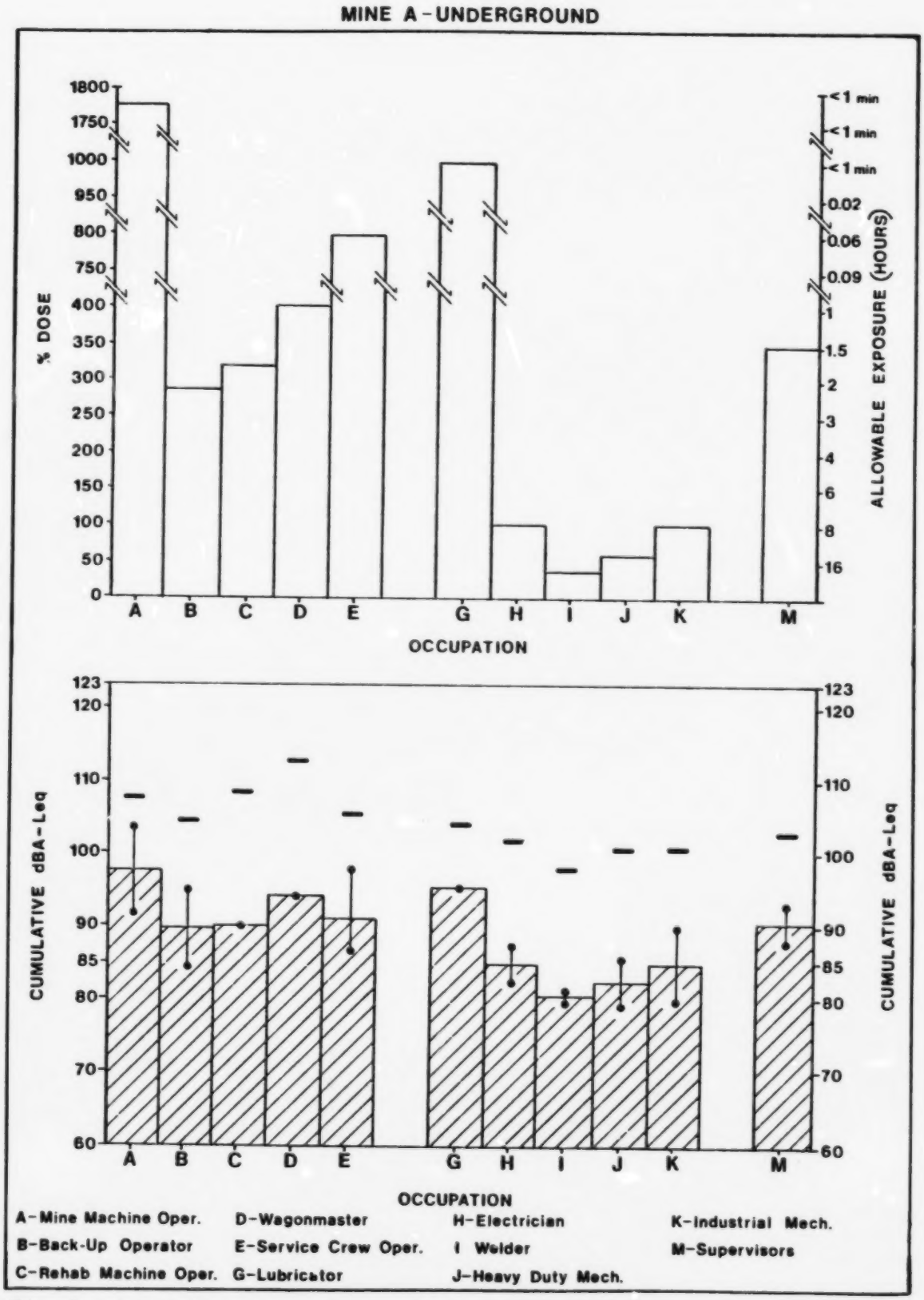

Fig. 2 - Comparison of cumulative dBA to percent dose/allowable exposure for each occupation underground at Mine A.

All other maintenance categories are low and several sound level meter tests verified these low levels. Production categories were all over 90 dBA, with the miner operator having the greater time weighted average. These figures, particularly those who are working with and around the mining machines can vary considerably depending on the operating period of the equipment, the proximity of the noise source to the operator and how often and how long the equipment is operating.

MINE B

In the surface group there were 64 tests and 47 underground tests for a total of 111, making this mine the least surveyed of the four. Of 23 occupations tested on the surface, 4 were 85 dBA or lower. The highest time weighted average values are found generally in the production crews, this being mainly due to plant noise from various pumps, blowers, screens and cyclones. Maintenance crews had the lowest time weighted average due to shop areas being less noisy and work in the mill usually occurring during maintenance shut-downs. Loadout was marginally higher than maintenance with the weighmaster occupation having the highest reading, but since only one sample was taken this result may not be indicative of that job category.

In the underground area there were a total of 13 different job categories tested, and in only two were the levels below 85 dBA. Production crews had the highest noise levels with the occupation of miner operator being the highest. Maintenance crews were, with few exceptions, well above 85 dBA, but because few samples were taken at this mine, and the ability to perform random sampling was limited, it is difficult to explain these high readings. The Brüel and Kjaer, sound level meter was used to sample throughout the mill and underground. In some cases the high readings, which were first seen from the personal noise dosimetry tests were verified. Most often though, the areas when checked with the sound level meter did not have noise levels as

Table 3 - Number of tests, time-weighted average, and rank for various job categories on surface at Mine B.

Job Category	No. of Tests	Time Weighted Average (dBA)	Rank
Utility Man	3	98	2
Screening Operator	4	99	1
Grinding Operator	4	92	3
Flotation Operator	4	92	3
Centrifuge/Dryer Operator	4	92	3
Compaction Operator	4	98	2
Crystallizer Operator	4	89	5
Reagent Operator	2	87	7
Loadout Operator	3	85	9
Car Loader	4	86	8
Weighmaster	1	89	5
Electrician	3	90	4
Industrial Mechanic	2	89	5
Industrial Mechanic (Wet End)	3	90	4
Industrial Mechanic (Dry End)	3	92	3
Heavy Duty Mechanic	1	82	10
Welder	4	92	3
Machinist	1	85	9
Sandblaster/Painter	2	88	6
Construction Man	1	89	5
Stationary Engineer	4	90	4
Instrument Man	2	89	5
Carpenter	1	81	11

Table 4 - Number of tests, time-weighted average, and rank for various job categories underground at Mine B.

Job Category	No. of Tests	Time Weighted Average (dBA)	Rank
Miner Operator	4	102	1
Loader/Bridge Operator	3	87	5
Equipment Operator	5	91	2
Car/Haulage Operator	3	85	7
Construction	3	89	3
Service Operator	1	87	5
Cage Tender	1	79	8
Warehouse	2	79	8
Ventilation Man	1	88	4
Electrician	7	87	5
Industrial Mechanic	10	87	5
Heavy Duty Mechanic	4	86	6
Welder	3	89	3

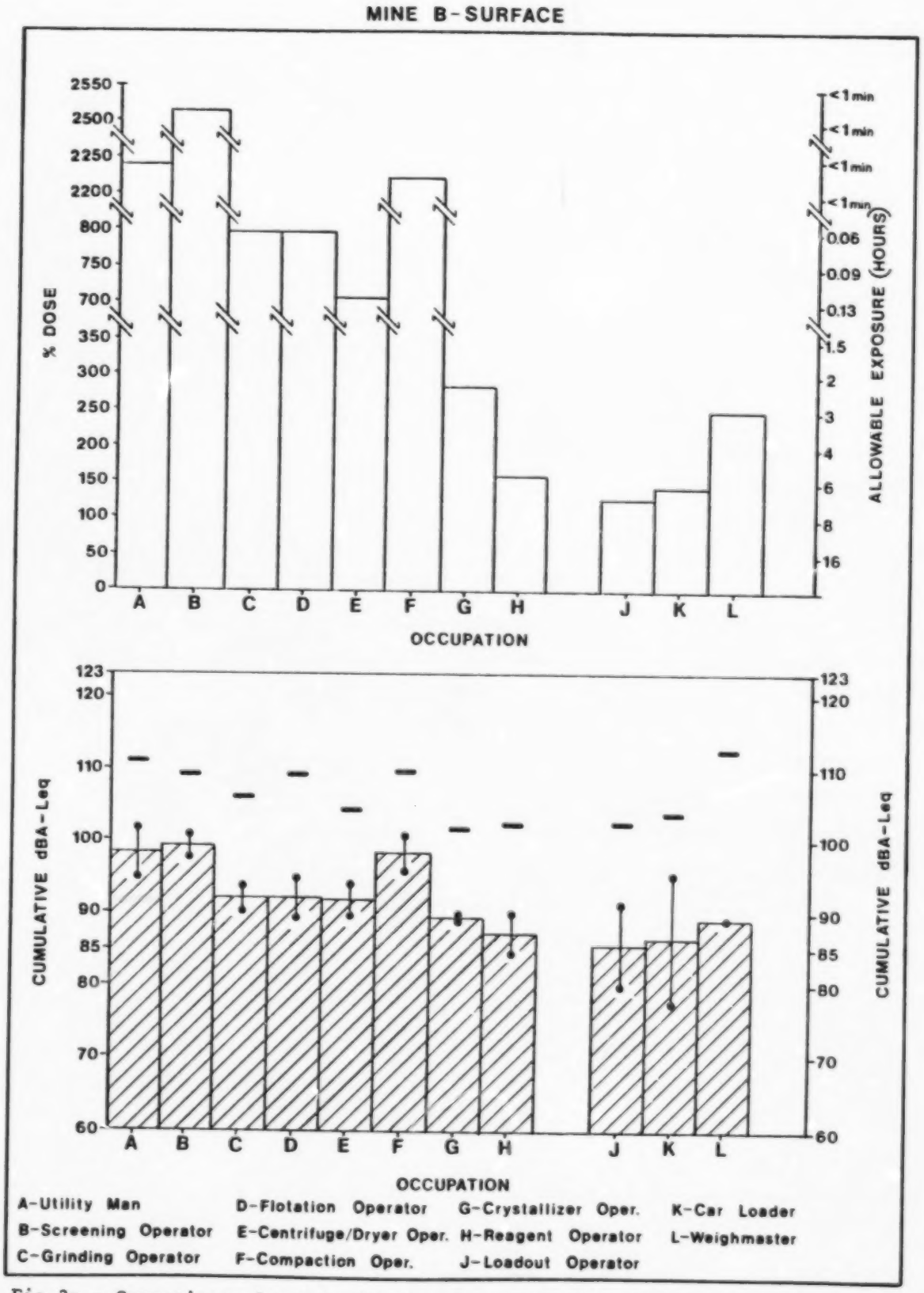

Fig.3a - Comparison of cumulative dBA to percent dose/allowable exposure for each occupation for surface at Mine B.

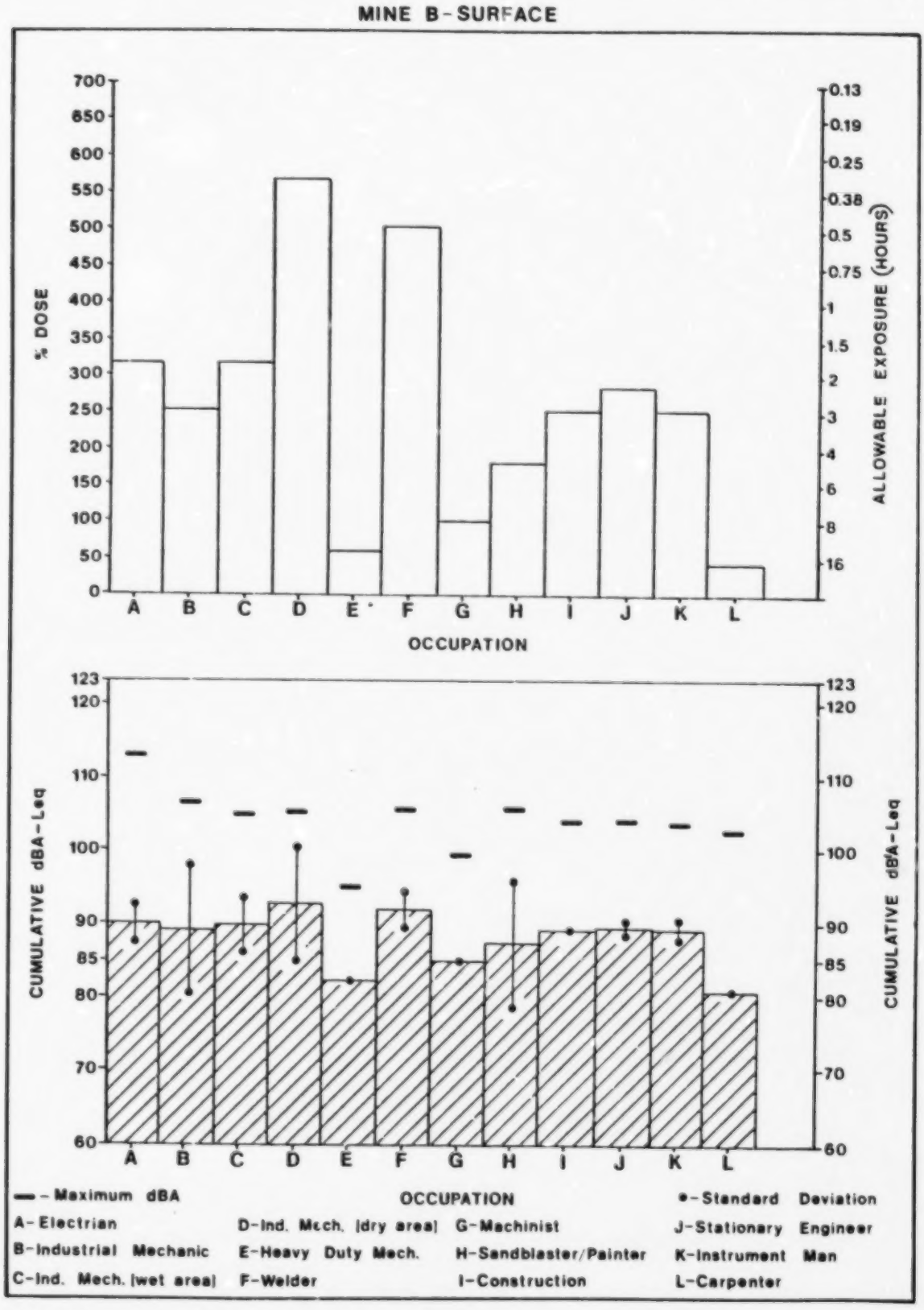

Fig. 3b - Comparison of cumulative dBA to percent dose/allowable exposure for each occupation for surface at Mine B.

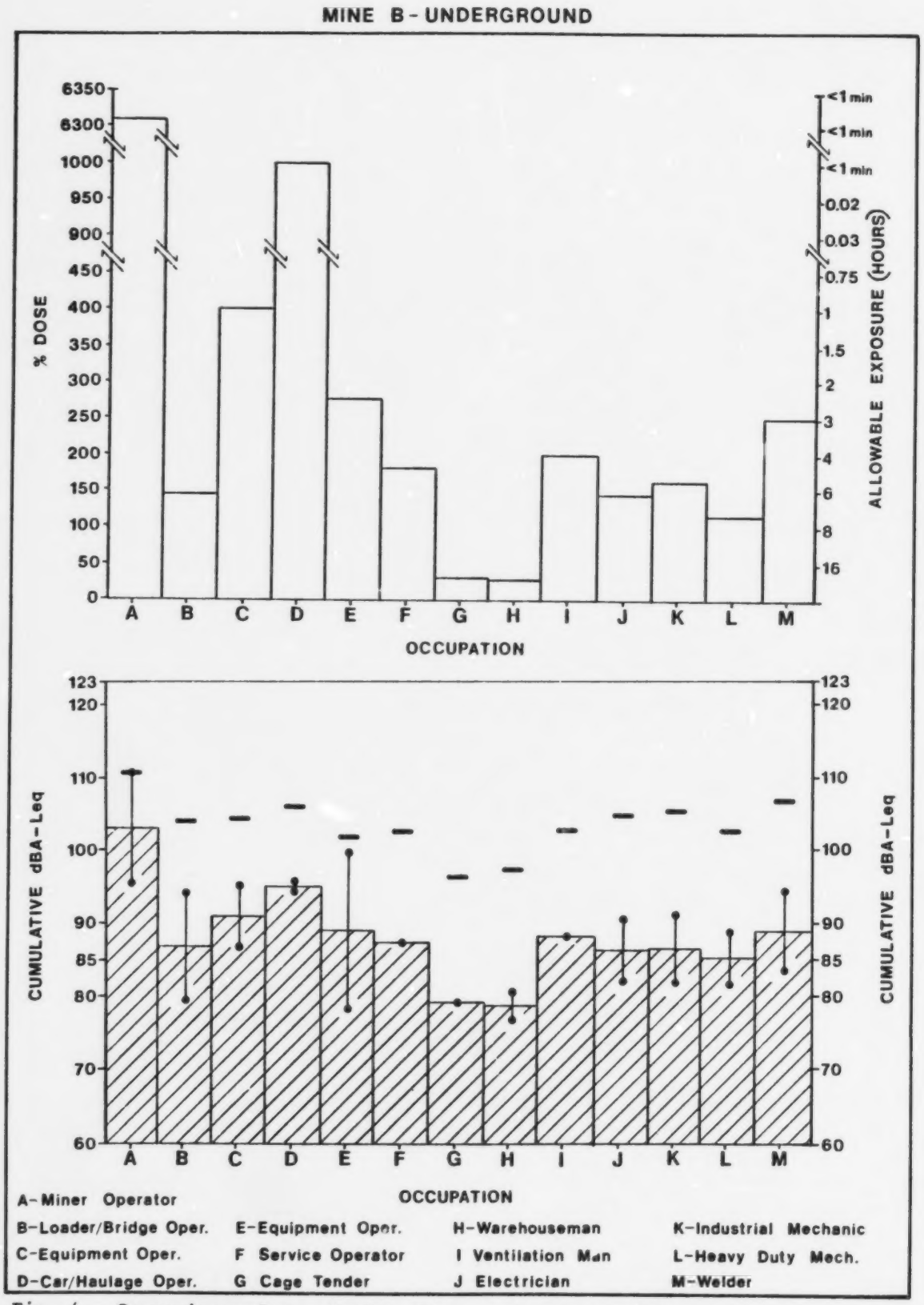

Fig. 4 - Comparison of cumulative dBA to percent dose/allowable exposure for each occupation underground at Mine B.

high as the loggers indicated, rather, they compared with previous values attained by the Occupational Health and Safety Branch of the Saskatchewan Government.

MINE C

A larger number of tests and categories were achieved due to a longer time period and a more flexible schedule. There were a total of 160 tests with a nearly equal dispersion of 81 surface, 79 underground. There were 27 different job occupations on the surface which were tested and 7 of those had a time weighted average of 85 dBA or under. Like the previous two mines, the noisiest occupations were in the production crews, but the variation in noise levels within production was such that some of the least noisy occupations were also found within this group.

On surface there is very little difference in noise levels between production and maintenance crews. The sandblaster/painter had the highest noise level followed by the caterpillar operator in the loadout area. The stationary engineer had one of the lowest noise levels, and the reason for this extreme contrast was due to the construction of a new control room away from the boiler area and the use of computers to monitor and allow adjustments to be made from within the control booth.

Underground, 10 of 18 occupations had time weighted averages of 85 dBA and under, with the highest noise areas also being in production. In the underground area the miner operator, and the back-up operator have, as expected, a high time weighted average, and some of the construction crews have cumulative values which are higher. The high time weighted average for the construction crews may be due to engine noise from various pieces of diesel powered equipment which are used to repair or extend conveyor belts. The maintenance crews generally have a low time weighted average. Most occupations have cumulative values below 85 dBA, and the large sample size

Table 5 - Number of tests, time-weighted average and rank for various job categories on surface at Mine C.

Job Category	No. of Tests	Time Weighted Average (dBA)	Rank
Crushing Operator	4	89	5
Screening Operator	5	88	6
Filtration Operator	4	90	4
Flotation Operator	6	88	6
Compaction Operator	6	91	3
Crystallization Operator	4	88	6
Spare/Utility Operator	1	86	8
Day Crew/Utility Operator	2	80	13
Reagent Operator	1	86	8
Laboratory Technician	1	82	11
Stationary Engineer	3	78	14
Central Control Room Operator	3	77	15
Shift Boss	4	90	4
Scale-Room Operator	1	87	7
Trackmobile Operator	1	89	5
Cat/Reclaimer Operator	4	92	2
Sampling/Sealing Operator	2	86	8
Loadout Supervisor	2	91	3
Industrial Mechanic	11	88	6
Heavy Duty Mechanic	2	86	8
Machinist	2	85	9
Welder	3	87	7
Pipe Fitter	1	84	10
Equipment Operator	2	89	5
Carpenter	1	81	12
Electrician	4	87	7
Sandblaster/Painter	1	93	1

Table 6 - Number of tests, time-weighted average, and rank for various job categories underground at Mine C.

Job Category	No. of Tests	Time Weighted Average (dBA)	Rank
Miner Operator	8	90	2
Extensible Operator	7	89	3
Dispatcher	1	68	14
Production Foreman	1	81	10
Rehab/Conveyor/Mobile Equipment Op.	4	88	4
Belt Patrolman	1	89	3
Back-up Operator 2	4	95	1
Back-up Operator 3	10	87	5
Construction Foreman	1	88	4
Surveyors	3	79	11
Industrial Mechanic	15	84	8
Heavy Duty Mechanic	2	83	9
Welder	2	86	6
Machinist	1	78	12
Electrician	13	84	8
Hoistman	1	72	13
Helper	2	85	7
Warehouse	3	79	11

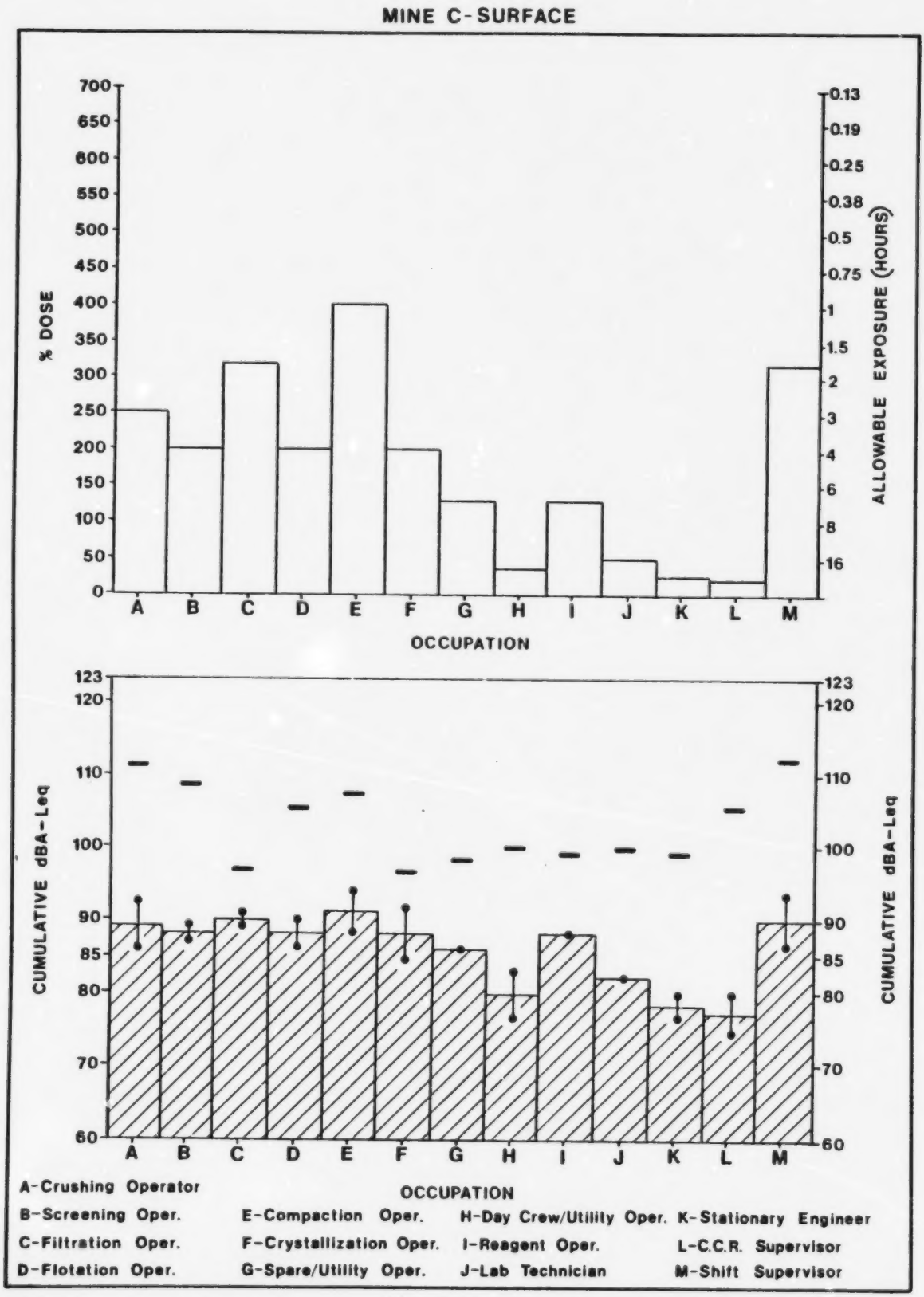

Fig. 5a - Comparison of cumulative dBA to percent dose/allowable exposure for each occupation for the surface at Mine C.

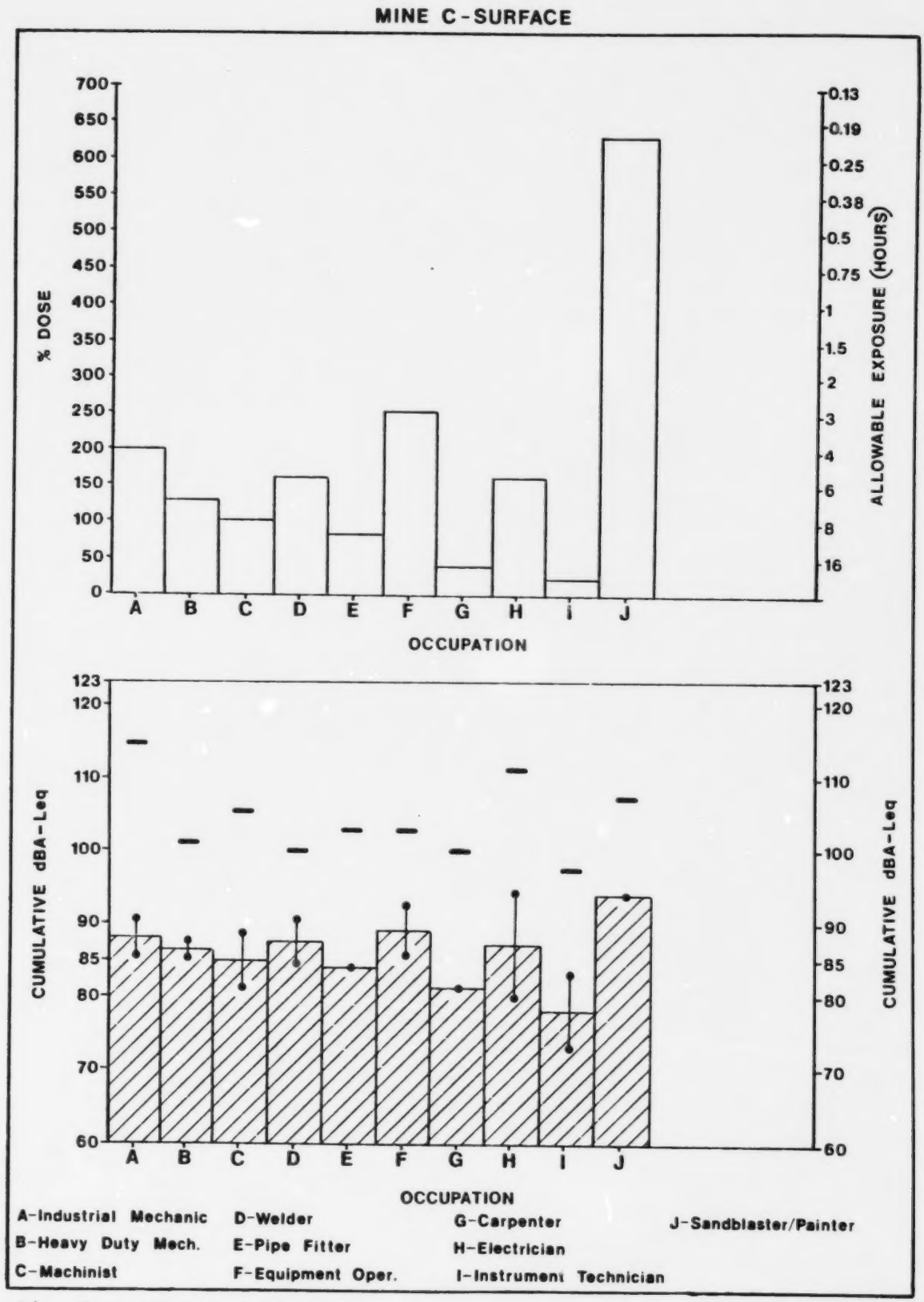

Fig. 5b - Comparison of cumulative dBA to percent dose/allowable exposure for each occupation for the surface at Mine C.

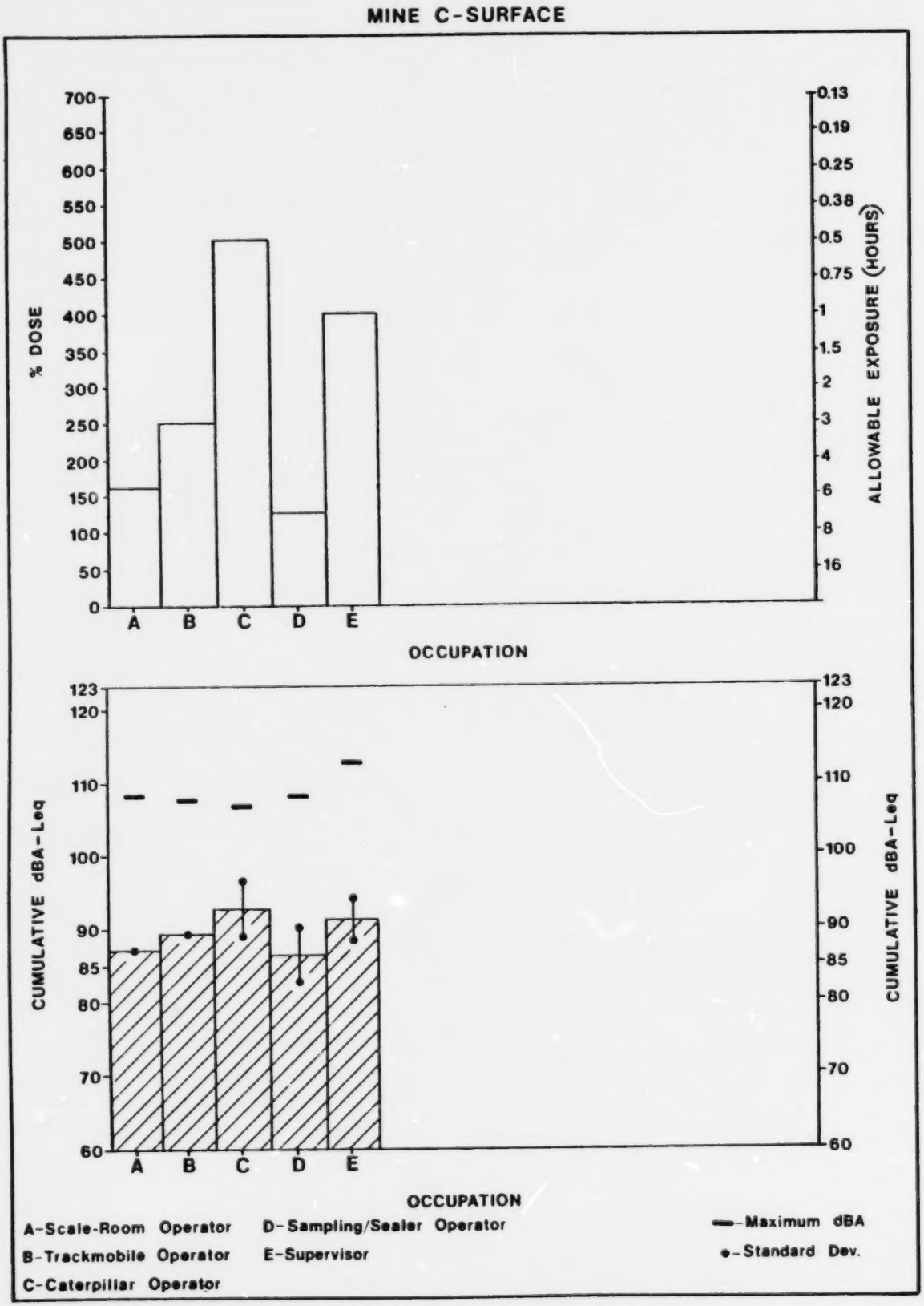

Fig. 5c - Comparison of cumulative dBA to percent dose/allowable exposure for each occupation for the surface at Mine C.

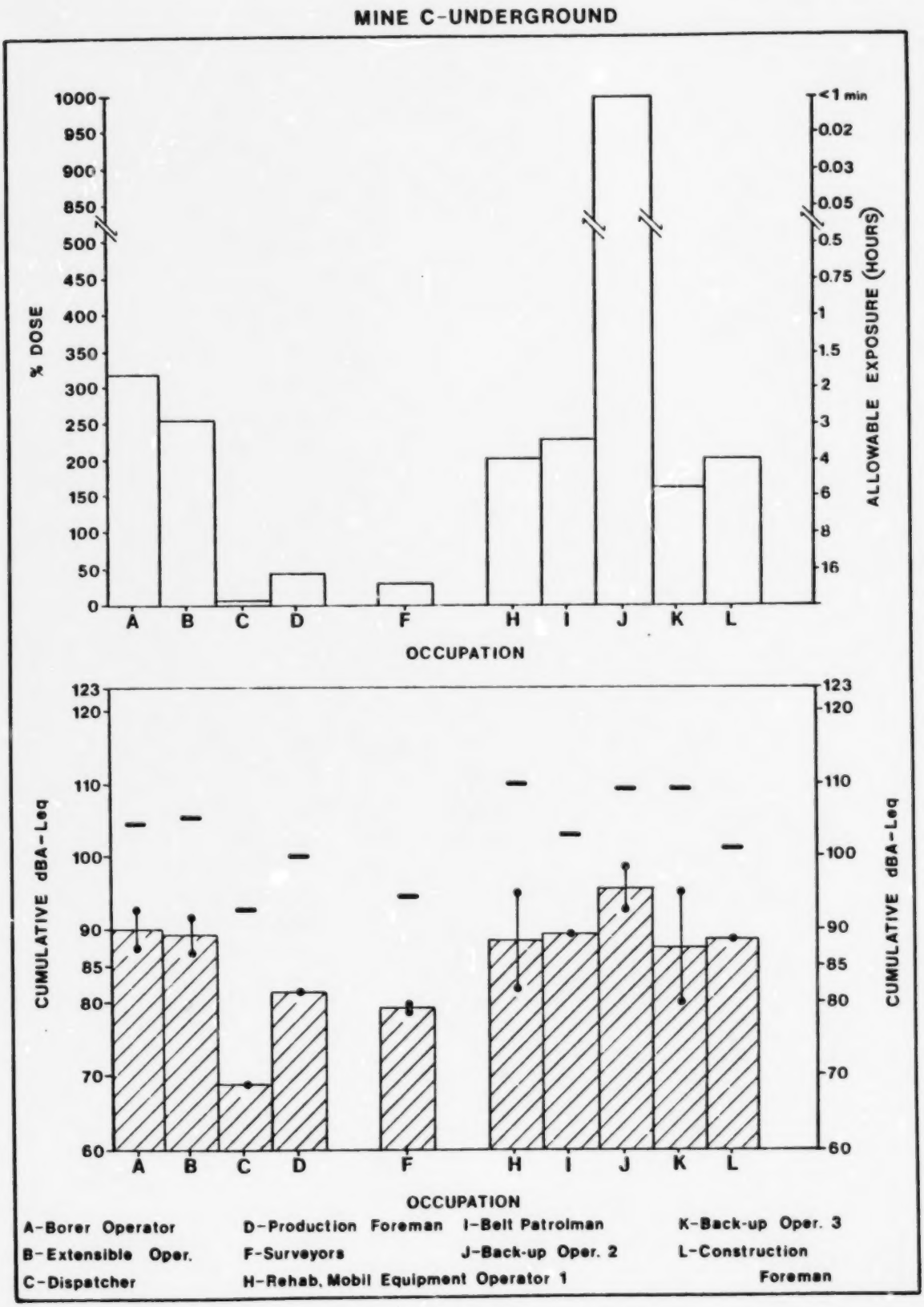

Fig. 6a - Comparison of cumulative dBA to percent dose/allowable exposure for each occupation underground at Mine C.

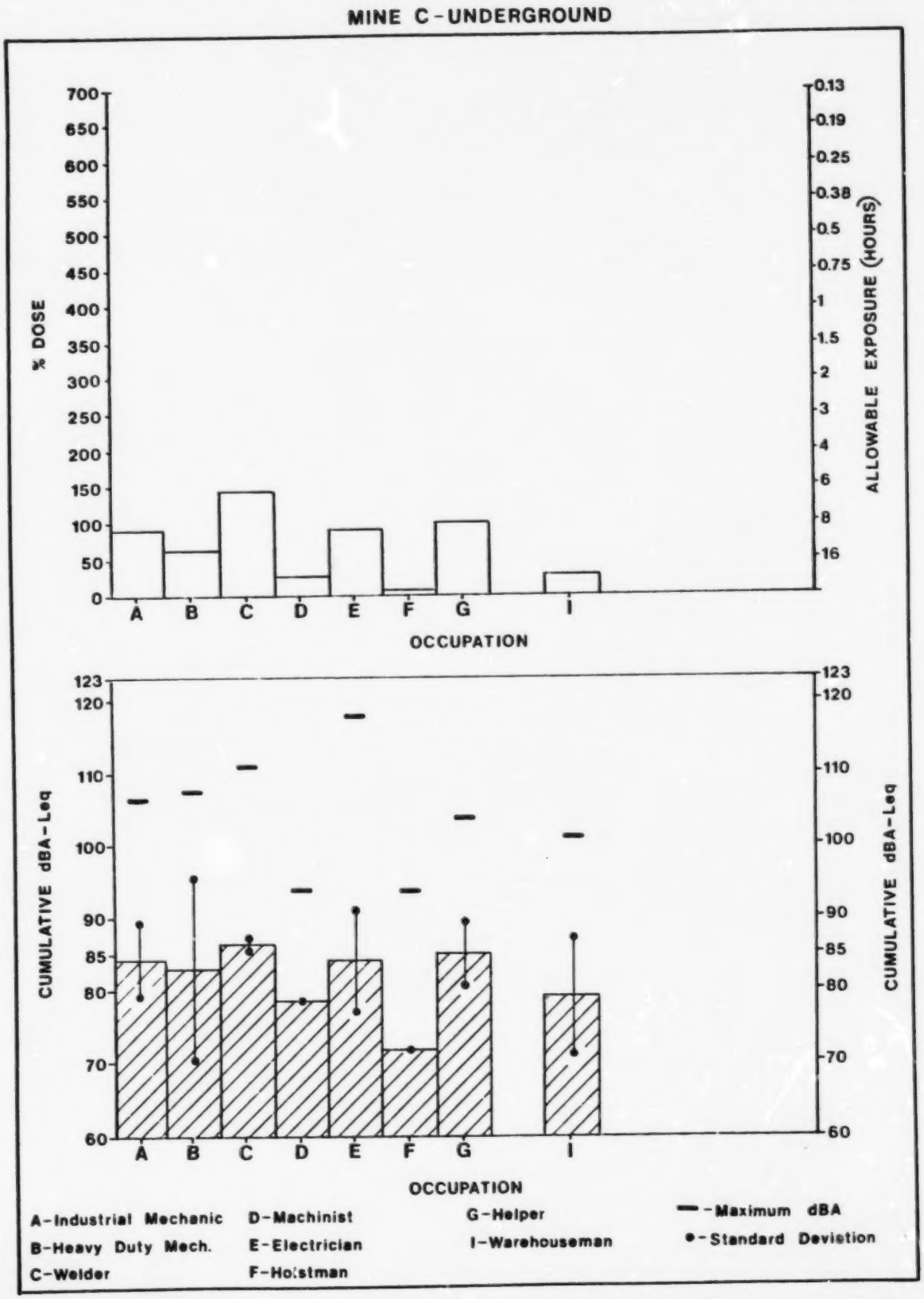

Fig. 6b - Comparison of cumulative dBA to percent dose/allowable exposure for each occupation underground at Mine C.

gives credibility to the accuracy of these results.

MINE D

This was the final mine surveyed and it received the most extensive testing. Of the 203 tests performed, 127 were on the surface and 76 underground. The shift schedule at this mine made underground testing difficult, thereby limiting the number of tests which could be performed in the time frame.

On surface there were 34 groups tested, and 12 were under 85 dBA. The categories with time weighted averages over 85 dBA are distributed throughout the production and maintenance crews.

The mill production crew, with the exception of one job category, had a time weighted average greater than 85 dBA. Background noise in the mill probably accounts for the high noise levels and the control room operator's low time weighted average validates this. In the loadout area, all job categories except for supervisor were over 85 dBA. The maintenance crew, as expected, had variable results. The sandblaster/painter, plumber/gas fitter and stationary engineer have the highest time weighted averages, which are likely due to working with compressed air. Because of the nature of their work, the sandblaster/painter and plumber/gas fitter will have great variability in their time weighted averages depending on their work load and scheduling.

Underground, 9 of 15 job categories had a time weighted average over 85 dBA. As was found in the other mines, the noisiest occupations were in production, all having cumulative values over 90 dBA. The occupation with the highest noise level was the rehab operator who is part of the construction crew, and this is likely due to diesel equipment which is used for conveyor belt extension and repair. Maintenance crews had a high time weighted

Table 7 - Number of tests, time-weighted average, and rank for various job categories on surface at Mine D.

Job Category	No. of Tests	Time Weighted Average (dBA)	Rank
Raw Ore Operator	5	90	5
Screening Operator	19	92	3
Flotation Operator	11	88	7
Crystallizer Operator	6	91	4
Spare/Utility Operator	5	89	6
Metallurgical Lab. Technician	1	85	10
Sample Runner	2	90	5
Pumps & Tails Operator	7	93	2
Control Room Operator	3	78	15
Scale Room Operator	4	86	9
Locomotive Operator	3	87	8
Cat/Reclaim Operator	3	85	10
Loading/Sealing Operator	2	86	9
Industrial Mechanic	8	86	9
Heavy Duty Mechanic	1	74	17
Automotive Mechanic	1	85	10
Machinist	2	86	9
Welder	4	86	9
Pipefitter	1	83	12
Plumber/Gas Fitter	1	92	3
Lubeman	1	87	8
Stationary Engineer	3	92	3
Sandblaster/Painter	3	94	1
Fire Marshall	1	90	5
Tool Crib Man	1	83	12
Electrician	8	84	11
Maintenance Planner	1	77	16
Instrument Technician	3	88	7
Safety Inspector	1	91	4
Carpenter	2	81	16
Warehouse Man	2	77	16
Production Supervisor	6	89	6
Storage & Loadout Supervisor	4	82	13
Maintenance Supervisor	2	87	8

Table 8 - Number of tests, time weighted average, and rank for various job categories underground at Mine D.

Job Category	No. of Tests	Time Weighted Average (dBA)	Rank
Mine Operator	20	91	3
Extensible/Tub Operator	4	93	2
Cross-Conveyor Operator	13	91	3
Rehab/Conveyor/Mobile Equipment Op.	2	95	1
Belt Maintenance Operator	3	87	6
Ventilation Operator	1	83	9
Water Pumping Operator	1	86	7
Industrial Mechanic	8	83	9
Heavy Duty Mechanic	1	83	9
Electrician	12	85	8
Welder	2	90	4
Shaft Maintenance	1	88	5
Mine Engineering Technician	3	80	10
Warehouse Man	1	77	11
Supervisors	4	86	7

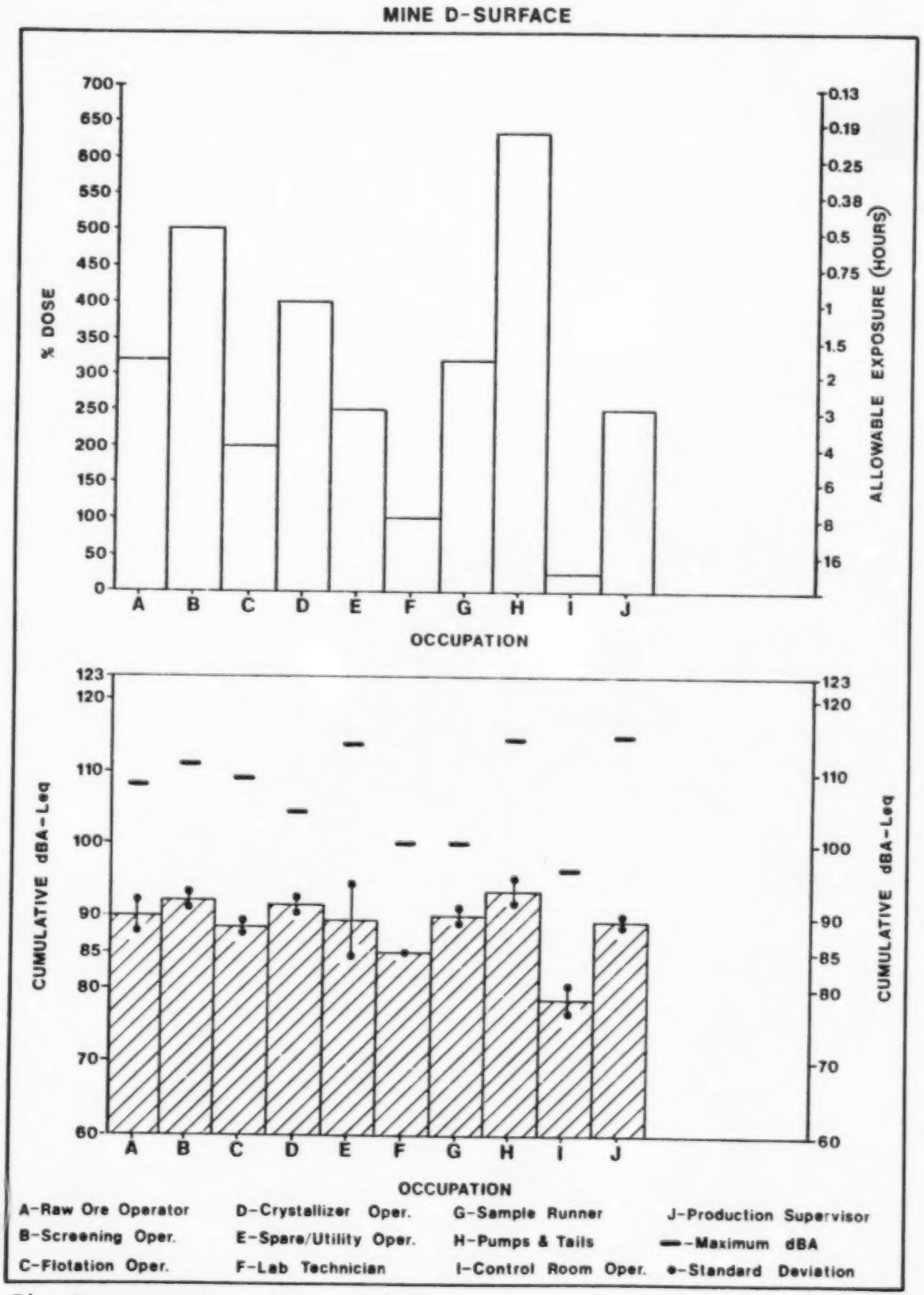

Fig. 7a - Comparison of cumulative dBA to percent dose/allowable exposure for each occupation on surface at Mine D.

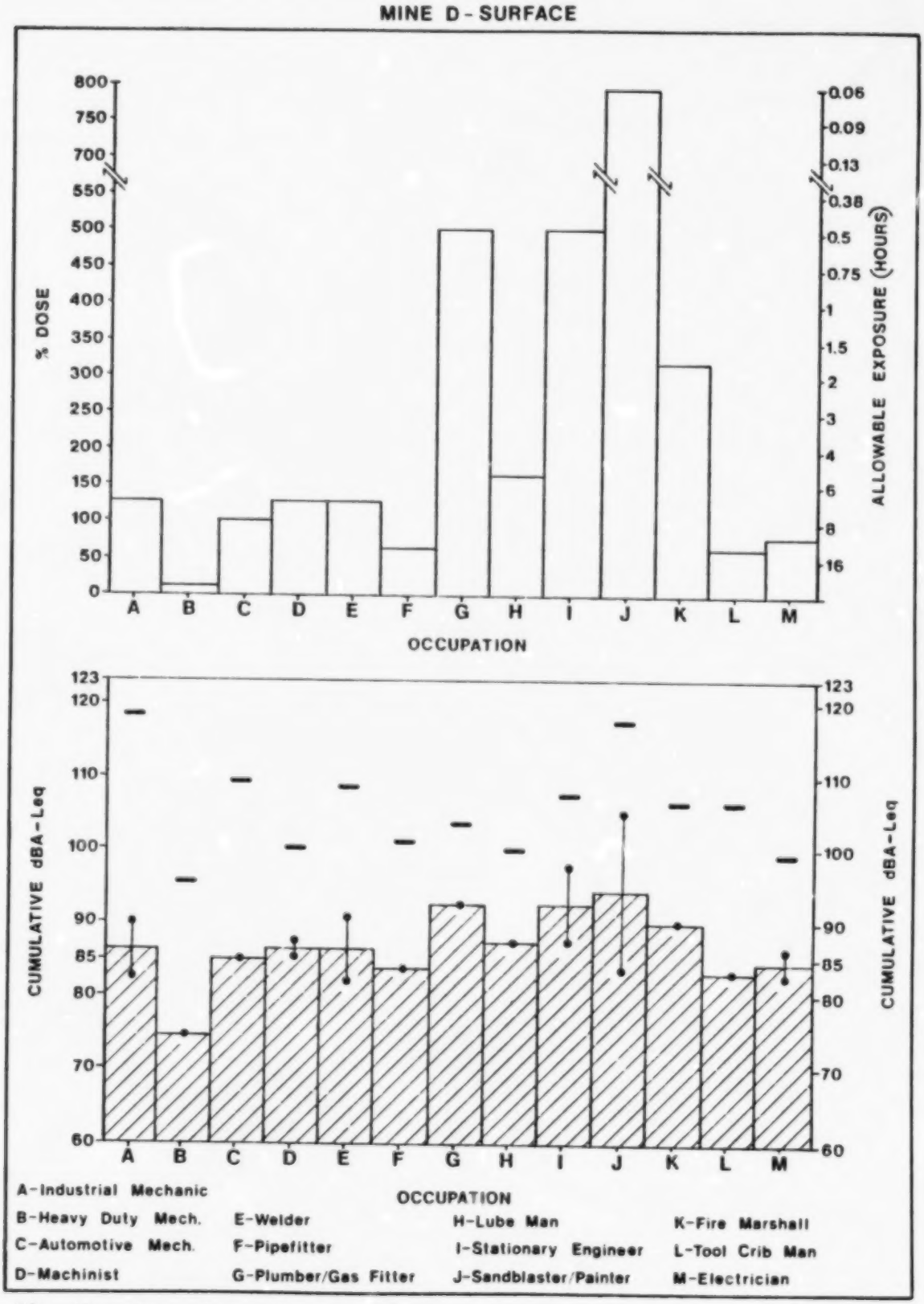

Fig. 7b - Comparison of cumulative dBA to percent dose/allowable exposure for each occupation on surface at Mine D.

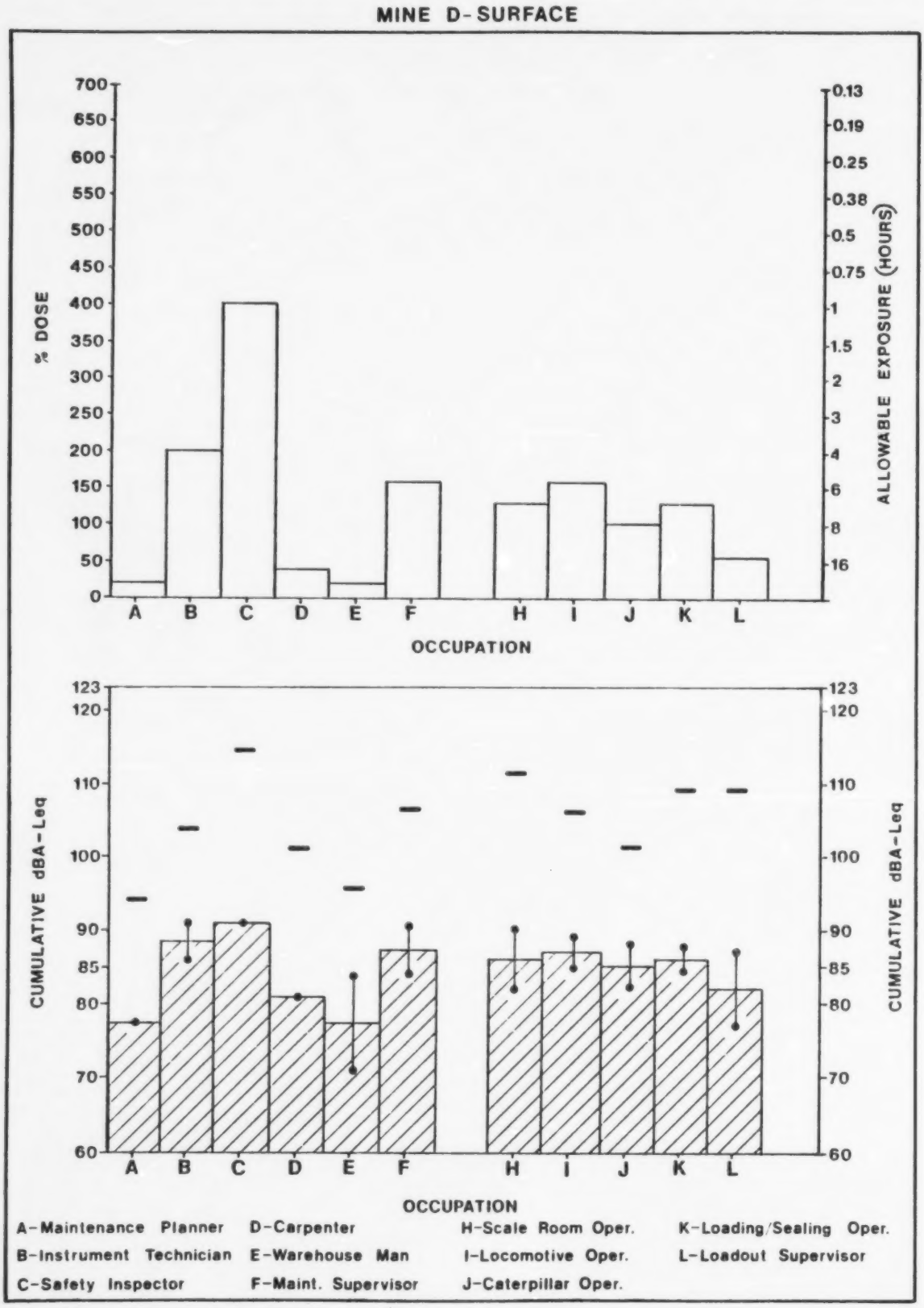

Fig. 7c - Comparison of cumulative dBA to percent dose/allowable exposure for each occupation on surface at Mine D.

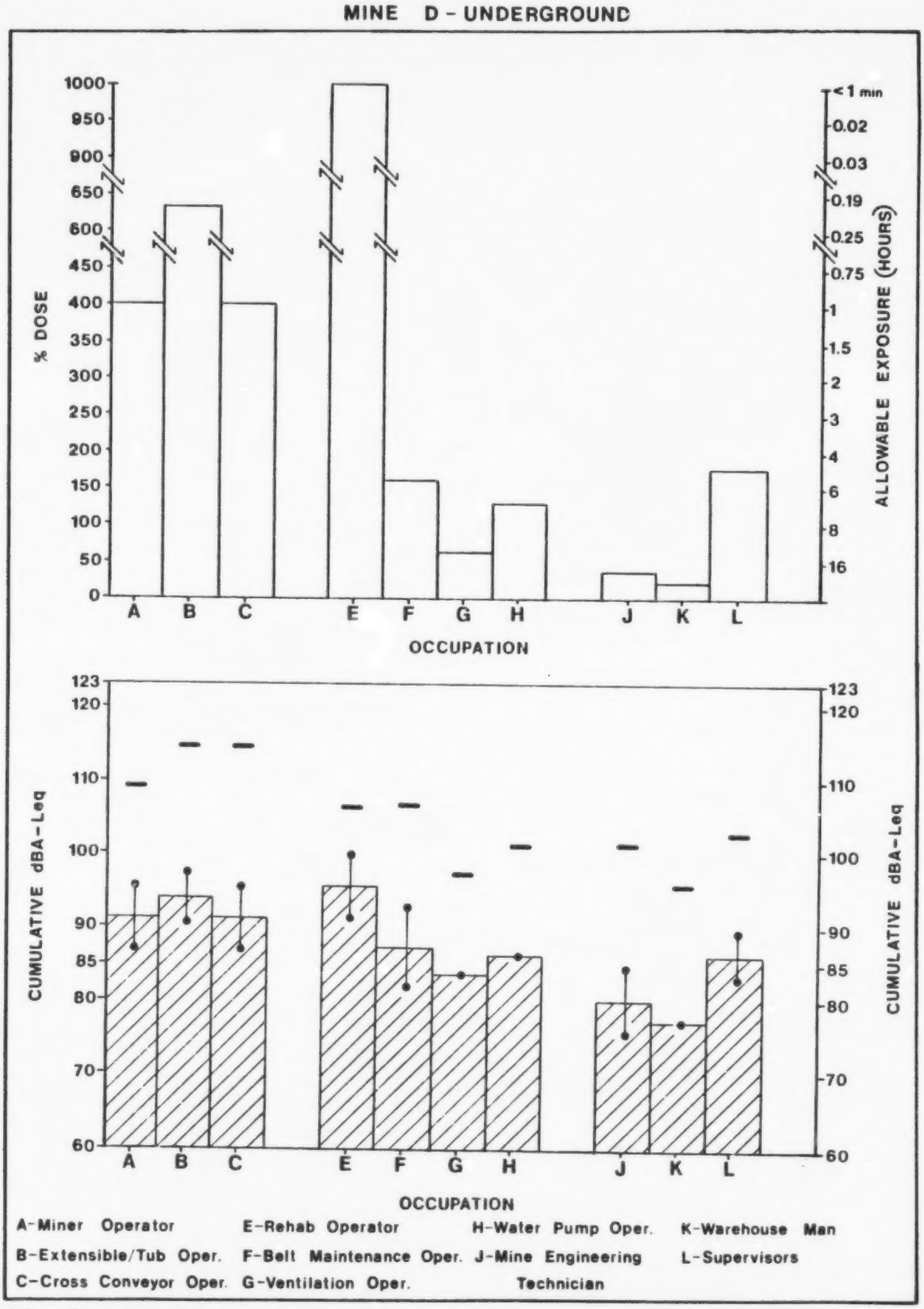

Fig. 8a - Comparison of cumulative dBA to percent dose/allowable exposure for each occupation underground at Mine D.

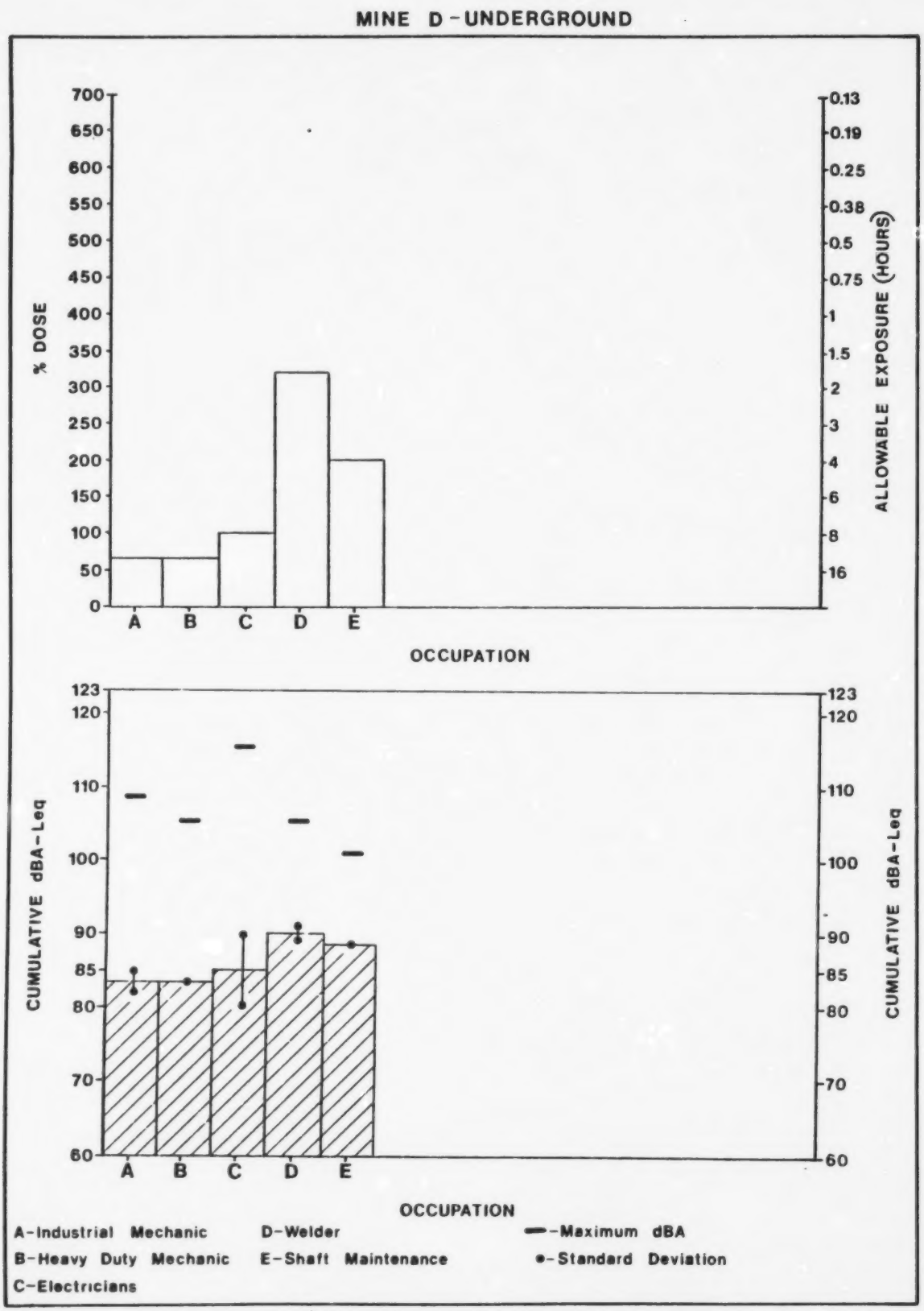

Fig. 8b - Comparison of cumulative dBA to percent dose/allowable exposure for each occupation underground at Mine D.

average, but the highest noise levels were found in occupations where only one or two samples were taken. Further testing would be required to validate these results.

CONCLUSION

The noise survey has reviewed the occupations throughout the various potash mines to determine their average cumulative level of noise exposure and recommends the following:

- further personal noise dosimetry testing should be conducted in order to produce data which include all occupations, with more frequent testing per occupation, for statistical accuracy;
- various types of noise measurements should be performed to efficiently analyze specific areas, in order to determine the most effective means of noise control;
- where there is any doubt about the noise level in a particular area, or for a specific occupation, an approved form of hearing protection should be worn;
- employees in job categories with higher exposure to noise could be given frequent audiometric tests by skilled technicians, and the results from these tests analyzed by qualified medical personnel;
- any changes, such as, new mining techniques, new equipment, renovation to existing work areas or construction of new work areas, could be done after determining if methods of noise control, and/or suppression can be feasibly incorporated with these changes;
- posted dBA readings, for surface and underground areas, should be periodically updated and these signs maintained and serviced so as to stress their importance to employees.

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